SEASONAL DISTRIBUTION OF PROTURA IN THREE DELAWARE FORESTS[1,2]

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ABSTRACT: Three forest sites were sampled bimonthly from May 1974 to April 1975 to determine the seasonal distribution and age structure of Protura. Two species were found, *Eosentomon vermiform* Ewing was present in all sites and *Acerella* species was present in two of them. Populations at two sites fluctuated with peak densities in the late summer (July-August) to early winter (September-December). Stable populations at the other site most likely relate to the habitat stability and forest age. Population age structure showed a predominance of adults throughout the year with most immatures occurring in July-August.

DESCRIPTORS: Protura; *Eosentomon, vermiforme* Ewing; *Acerella* sp.; seasonal distribution; population density; deciduous forests.

Protura are members of the soil fauna, a diverse assembledge of animals inhabiting the top few centimeters of the earth's surface. Ecologically these animals are detritivores and their predators. They exist in a region of high humidity, relative absence of air movement and more stable temperatures than surrounding areas (Kuhnelt 1961). Ewing (1940) referred to proturans as creatures of darkness, entirely defenseless and requiring humid conditions for survival. Protura are found under bark, in peat and moss, under stones and logs (Williams 1913), in permanent grasslands and pastures (Salt *et al.* 1948, Raw 1956, Lussenhop 1973), in oak and pine forests (Pearse 1946, Price 1973) and expressway margins (Lussenhop 1973). Much is known about their taxonomy, morphology and geographical distribution (Ewing 1940, Tuxen 1964, and Janetschek 1970), but their population structure and seasonal abundance has received limited attention (Pearse 1946, Raw 1956 and Price 1973).

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This paper presents results of a study on the seasonal abundance and population structure of Protura from three different forest areas in Delaware.

Methods and Materials

Three forest sites in Delaware were each sampled six times from May 1974 to April 1975. A core sampler with an 11.3 cm diameter was used. Ten cores were taken per site for each sampling period. Core depths varied from 8 cm to 12 cm depending on roots and the thickness of the humus layer. A plot was circular with six equally spaced radii along which the cores were removed at one meter intervals. One randomly selected radius was sampled at a sample time. Three additional samples were taken from each site for pH, organic content and chemical analysis.

Eight modified Burlese funnels with 25 watt light bulbs were used for collecting the proturans (Tuxen 1964, Phillipson 1971). Samples remained in the funnels for 72 hours. Samples that could not be run simultaneously were placed in refrigeration at 3.3-5.5°C for no more than 7 days. The proturans were separated into immatures, those with less than 12 abdominal segments, and adults, those with 12 abdominal segments.

Soil tests were done by the Soil Testing Laboratory at the University of Delaware. Temperature and rainfall data were taken from the closest reporting weather station. The Newark site was less than 1 km away, Woodside site 8.0 km and Georgetown site 4.8 km.

Site Description

All three study areas were located on the coastal plain of the Delmarva peninsula. Site one was located in the University of Delaware woodlot, Newark, Delaware. The forest is a maturing deciduous forest being approximately 100 years old and composed of white oak *(Quercus alba)*, tulip-tree *(Liriodendron tulipifera)*, hickories (*Carya* spp.), and sweet gum *(Liquidambar styraciflua)*. The understory is composed of ironwood *(Ostrya virginiana)*, dogwood *(Cornus florida)* and *Viburnum dentatum*. The dominant ground cover was mayapple *(Podophyllum pelatum)*. Soil type was Keyport silt loam (USDA 1970). The plot was located on a high mound and was well drained. Litter depth was approximately 2 cm and the humus was approximately 4 cm deep. The pH ranged from pH 4.1-4.6. Organic content ranged from 8-11 percent.

Site two was located in a predominately loblolly pine *(Pinus taeda)* forest approximately 3.2 km east of Woodside, Delaware. The forest was determined to be approximately 60 years old by tree core measurements of the loblolly pines. Other trees were sweet gum, tupelo *(Nyssa aquatica)*, holly *(Ilex opaca)* and white oak. A heavy stand of poison ivy *(Rhus radicans)* covered much of the ground in and around the plot. The soil was Woodstown loam (USDA 1971) with poor drainage and a 2-4 cm litter depth and a 4-6 cm humus layer. The pH ranged from pH 3.6-4.3 and the organic content varied from 8-19 percent.

Site three was located 5.6 km southwest of Georgetown, Delaware in an approximately 25 year old deciduous forest. The dominant species were red maple *(Acer rubrum)*, sweet gum, holly, a few oaks (*Quercus* spp.) and some loblolly pine. The predominate ground cover was scattered poison ivy. The soil was Fallsington sandy loam and was poorly drained (USDA 1974). Litter depth was approximately 2 cm and the humus 3-4 cm deep. The pH ranged from pH 3.4-4.0. The organic content was approximately 30 percent.

Magnesium (Mg) ranged from 16.7-21.9 ppm, phosphorus (P_2O_5) from 0.9-2.5 ppm and potash (K_2O) from 15.6-18.8 ppm in the three areas. No seasonal or site variations were observed. The pH at the three sites showed only a slight seasonal pattern. The highest pH occurred in July-August and March-April and the lowest in January-February.

Results

A total of 933 specimens was collected from the three sites. Two species, *Acerella* sp. (Acerentomidae) and *Eosentomon vermiforme* Ewing (Eosentomidae), were collected at sites one and two. Site three contained only *Eosentomon vermiforme.* Tuxen (pers. comm.) informed us that the *Acerella* species was very close to *A. canadensis* Tuxen but differed in some important points. We have decided to refer to it as *Acerella* species.

The population of *Eosentomon vermiforme* at Newark showed little seasonal change and had a mean density of 141/m^2 (range 71-190/m^2) (Fig. 1) and the adults remained dominate with the immatures reaching a peak in July-August (47.1%) (Table 1). The

Acerella sp. from Newark also showed a fairly uniform population with a mean density of $66/m^2$. This population reached a low during the winter with $20/m^2$ in November-December and $10/m^2$ in January-February. Immatures were found present only in the first two samples for *Acerella* sp. (Table 1).

At Woodside the *Acerella* sp. showed a high population density in late summer to early winter with a high in November-December of $2330/m^2$ (Fig. 2). This population high was preceded by a low of $86/m^2$ (May-June) and followed by a low of $188/m^2$ (March-April). *Eosentomon vermiforme* population also peaked in November-December ($130/m^2$) and then declined rapidly afterwards ($12/m^2$). The Woodside population had immatures present until the January-February sample when the populations were declining. The highest percentage of immatures for *Acerella* occurred in May-June (25%) and July-August (25.9%) and *E. vermiforme* contained 50% immatures in July-August and 28.6% immatures in November-December (Table 1).

The Georgetown population of *E. vermiforme* reached highs of $1390/m^2$ in September-October and $1050/m^2$ in November-December, these were preceded by a low ($30/m^2$) and followed by a low ($40/m^2$) (Fig. 3). The March-April samples at Georgetown were saturated with water. When cores were removed from the ground, water seeped into the holes. These samples did not provide any proturans in the 72 hours of collecting. The January-February sample at Georgetown was represented by four immatures, the May-June by four adults and July-August by two adults and one immature (Table 1).

The individual bimonthly samples and totals for the three sites all show clumped distributions of the proturans (Table 2). The distributions approach the Poisson but the coefficient of dispersion (CD) (Sokal and Rohlf 1969) in all but three of the samples (Newark, March-April; Woodside, July-August and March-April) is > 1 or < 1 indicating clumping or repulsion of the proturans from a random distribution as indicated by the Poisson distribution.

The rainfall per month fluctuated, being low in July, October and November and high in August, January and March for the three sites (Figs. 1, 2 and 3). The mean monthly temperatures for the three areas differ only by a degree or two. July and August temperatures were highest and January and February were lowest (Figs. 1, 2 and 3).

Figure 1. Estimated population density of *Eosentomon vermiforme* Ewing and *Acerella* sp. collected from Newark, DE from May 1974 to April 1975 (above). Total monthly rainfall (below, left) and mean monthly temperature (below, right).

Figure 2. Estimated population density of *Eosentomon vermiforme* Ewing and *Acerella* sp. collected from Woodside, DE from May 1974 to April 1975 (above). Total monthly rainfall (below, left) and mean monthly temperature (below, right).

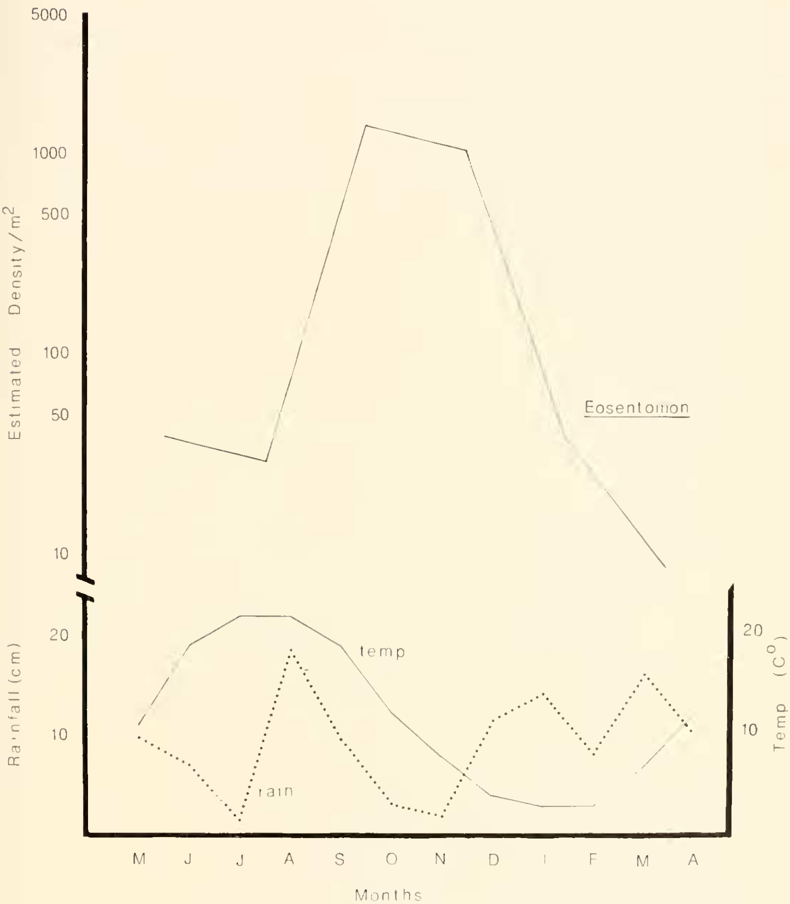

Figure 3. Estimated population of *Eosentomon vermiforme* Ewing collected from Georgetown, DE from May 1974 to April 1975 (above). Total monthly rainfall (below, left) and mean monthly temperature (below, right).

Discussion

The clumped distribution of the proturan species in the three forest areas is characteristic of many soil arthropods (Cole 1946). Price (1973) found highly aggregated distribution of a proturan species in coniferous forest soil and Raw (1956) found *Proturentomon minimum* (Gisin) and a species of *Eosentomon* from grasslands were aggregated and concluded that the degree of aggregation appeared to be independent of the population density. The aggregations observed are probably the result of highly favorable "micro" conditions within the structure of the soil (spaces, soil moisture, food, etc.) and slow dispersal rates from reproductive centers.

The uniformity of the Newark populations as compared to the eruptive populations at the other sites may relate to the stability of that habitat. The Newark site is well drained and never with standing water. The soil type (silt loam) will hold more moisture over a longer period of time and this coupled with the fairly uniform rainfall (Fig. 1) would provide a more constant environment. The age of the forest and maturity of trees would also provide a uniform litter fall to the soil. The population increases at Woodside and Georgetown correspond to the period of lowest total rainfall over a three month period (Sept., Oct., Nov.) (Figs. 2 and 3). This is also a period of declining average temperature from the summer mean maximum. However, this temperature phase continues until February. Pearse (1946) found that *Eosentomon pusillum* Ewing from an oak-pine forest in North Carolina showed no noticeable seasonal trends, but fluctuated irregularly. Price (1973) found a very definite seasonal trend for a proturan from a California pine forest. That unnamed species showed a peak population corresponding to the wet-winter months. The numerical dominance reversal of *Acerella* sp. between Newark and Woodside may be explained by the switch from a decidious litter at Newark to a coniferous litter at Woodside or a factor associated with this change. The reason for the absence of *Acerella* sp. from Georgetown is unknown to us.

Sturm (1959) observed *Acerentomon* sp. piercing the hyphae of a mycorrhizal fungus growing on oak and hornbeam *(Carpinus)* roots and a species of *Eosentomon* fed on both mycorrhizal fungi and free hyphae. Mycorrhizal fungi which are in association with the roots of all plants would be either dormant if on non-coniferous plants or less active if on conifers in the fall of the year (Harley 1969). This dormant or reduced activity period corresponds to the population increase at Woodside and Georgetown (Figs. 2 and 3). The mycorrhizal fungi on pines when active produce large amounts of toxins that have an inhibitory effect on numerous organisms (Marx 1972). The fungi on non-conifers *(Endogone)* do not produce any known toxins; however, they form sporocarps and have different ectocarpic resting spores of which most occur in the top 15 cm of the soil (Mosse 1973). These fungi in their dormant stage or reduced activity stage may serve as an added food source along with the decaying leaves on which they have been observed feeding (Ewing 1940).

The stability of the Newark populations may also be related to the food availability. The ground cover (mayapple) and amount of roots in the humus layer in Newark was less than at Georgetown and Woodside which probably resulted from a greater amount of ground cover (poison ivy). The mycorrhizal fungi at Newark would not be as abundant as at the other sites which may account for the lower abundance of Protura (Fig. 1) as compared to Woodside or Georgetown (Figs. 2 and 3).

We found immature proturans mainly in the late spring (May-June) and summer (July-August) samples at all sites for both species. The remaining samples contained relatively few immatures, with the spring (March-April) samples containing none (Table 1). The greatest percentage of immatures in any population corresponds to the period of highest mean temperatures and the period of most food production. The presence of immatures in other sample periods indicates either an annual life history (Phillipson 1971) or continued reproduction into the cooler months.

TABLE 1.

POPULATION AGE STRUCTURE OF PROTURA FROM THREE FOREST AREAS IN DELAWARE COLLECTED FROM MAY 1974 TO APRIL 1975.

Species	Collection Date and % of Adults/Immatures					
	May-June	July-Aug	Sept-Oct	Nov-Dec	Jan-Feb	March-April
Site One: Newark						
E. verniforme	78.0/22.0	52.9/47.1	100/-	92.8/7.2	88.9/11.1	100/-
Acerella sp.	66.7/33.3	80.0/20.0	100/-	100/-	100/-	100/-
Site Two: Woodside						
E. verniforme	80.0/20.0	50.0/50.0	100/-	71.4/28.6	-/-	100/-
Aceralla sp.	75.0/25.0	74.1/25.9	90.6/9.4	92.8/7.2	100/-	100/-
Site Three: Georgetown						
E. verniforme	100/-	66.7/33.3	97.8/2.2	93.0/7.0	-/100	-/-

TABLE 2.

POPULATION STATISTICS FOR PROTURA FROM THREE FOREST AREAS IN DELAWARE COLLECTED FROM MAY 1974 TO APRIL 1975.

	Collection Date						Total
	May-June	July-Aug	Sept-Oct	Nov-Dec	Jan-Feb	March-April	
			Site One: Newark				
Mean	2.0	2.2	2.4	1.6	2.0	1.7	1.9
S.D.	4.83	4.42	1.71	2.22	2.67	1.77	3.06
C.D.	2.14	2.00	0.71	1.38	1.33	1.04	1.56
			Site Two: Woodside				
Mean	1.4	9.2	14.8	24.6	4.5	1.7	9.3
S.D.	2.37	9.25	20.08	30.17	5.34	1.64	17.11
C.D.	1.69	1.00	1.35	1.22	1.18	0.96	1.82
			Site Three: Georgetown				
Mean	0.4	0.3	13.9	10.5	0.4	–	3.9
S.D.	0.97	0.48	12.08	7.96	0.69	–	8.03
C.D.	2.42	1.60	0.86	0.75	1.72		2.04

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